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REPORT NO. 1126
MARCH 1961

A SINGLE CHART SYSTEM OF INTERIOR BALLISTICS

R. C. Strittmater

Department of the Army Project No. 503-02-001
Ordnance Management Structure Code No. 5010.11.813
BALLISTIC RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

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B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

REPORT NO. 1126

RCStrittmater/dhs
Aberdeen Proving Ground, Md.
March 1961

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ABSTRACT

There is presented the very simple graphical method which has been used in the Interior Ballistics Laboratory during the past few years to make estimates of the interior ballistic performance of guns. Theory is not discussed; how-to-do-it is given in cookbook fashion. A foreword offers historical comment.

FOREWORD

Mr. Richard Strittmater presents here the method he has developed and used to make estimates of interior ballistic performance of guns during the past year or so. Acknowledgment must be made of the preceding extensive efforts of Delmar Boyer, Bernard Jansen, Wilbur W. Blakely, Leonard F. Kilian, who have each developed at least one more or less similar system and who have provided, in total, a considerable experience with various methods and correction schemes. Their work, not presented in formal reports, has been available to Mr. Strittmater, and has indeed suggested the form of the present method.

The characteristic features common to all these methods have been 1) the elimination of quantities not directly observed such as those which describe the situation at the instant the burning of the propellant is completed, and 2) the expression of the resulting relations graphically in terms of fully reduced variables whose interrelations can then be presented graphically on a single page. Those problems in which the rate of burning of the propellant does not appear have been well over 90% of the total in this Laboratory, nearly all of them early preliminary considerations of gun design. These problems are treated directly with utmost simplicity as Strittmater here demonstrates. One who is suspicious of corrections or adjustments by other people's empirical formulas can easily plot several discrepancy diagrams (polygons consisting of curves of the chart which would be concurrent if the firing data fitted this system exactly. They are more frequently called "the little triangles". They are shown in Figure 2.) for one or several reference firings, mull over the discrepancies thus clearly presented, and finally make his own adjustment graphically by making a discrepancy diagram for the required prediction. This unmathematical procedure has been found very satisfactory, well received by both practitioners and customers. A customer who requests an estimate of interior ballistic performance is nearly always interested in the discrepancy diagrams and what they indicate as to the reliability of the estimate in various respects.

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Mr. Delmar Boyer has carried out numerically a similar reduction for a variety of conventional interior ballistic systems. Here Mr. Strittmater presents only the Mayer-Hart method since it is simple, and since, used in this way, it seems to give as good engineering estimates as any. To simplify the exposition and make the scheme as widely and easily available as possible, he has presented it in a cookbook, how-to-do-it fashion.

Experience here has indicated that accuracy and reliability of these estimates depends far less on the choice of system than on the persistence, ingenuity, and experience brought to bear on checking and rechecking the statement of the problem, the reference data, and the results.

The less frequently occurring problems which involve burning rates are handled similarly by use of a scale for the quantity W, the central ballistic parameter, which appears at the top of the chart.

In conjunction with Mr. Strittmater's BRLM Report No. 1299, which presents an alignment chart to compute estimates of charge weights without guessing and iterating, the scheme presented here reduces interior ballistic calculations to procedures of minimum effort and, we think, of maximum reliability, a reliability which results not from any deeper more penetrating insight it provides, but rather from its simplicity which simplifies and encourages thoughtful comparison of a problem situation with a variety of known results.

William C. Taylor

WILLIAM C. TAYLOR

A SINGLE CHART SYSTEM OF INTERIOR BALLISTICS

A chart is presented that will give solutions rapidly to some common problems in interior ballistics. The Mayer-Hart[1] assumptions were made in writing the equations on which the chart is based. It was also assumed that bore friction is proportional to chamber pressure. This is equivalent to giving the projectile an effective mass somewhat higher than its actual mass. This assumption provided a factor which could be tailored to bring chart and experiment into closer agreement. The data from 165 firing records were compared with the chart and a form for the effective mass of the projectile was determined which considerably improved the agreement of chart with experiment.

Procedure for the Use of the Chart

The reduced variables represented on the chart (Figure 1) are:

ballistic efficiency

$$e = \frac{\gamma-1}{2}\ \frac{(M+C/3)V^2}{386\ FC} = .15\ \frac{\left[m+C/3+\frac{10^6 DL}{2V^2}\right]V^2}{386\ FC},$$

piezometric (zaroodny) efficiency

$$z = \frac{\frac{1}{2}\left[m+C/3+\frac{10^6 DL}{2V^2}\right]V^2}{386\ P_{max}\ (U-C/\rho+AL)},$$

free volume expansion ratio

$$x = \frac{U-C/\rho+AL}{U-C/\rho},$$

a ballistic parameter

$$r = \frac{FC/U_o}{P_{max}} = \frac{FC}{P_{max}(U-C/\rho)},$$

---

[1] Simplified Equations of Interior Ballistics, Joseph E. Mayer and B. I. Hart, Journal of the Franklin Institute, Vol. 240, No. 5, Nov. 1945

the muzzle to peak pressure ratio

$$y = \frac{P_m}{P_{max}}$$

where the notation is as follows:

m is the mass of projectile		lb.
F is the specific force of the propellant		$\frac{\text{in. lb. wt.}}{\text{lb.}}$
C is the mass of the propellant		lb.
M is the effective mass of the projectile	$m\left[1+\frac{10^6 DL}{2mV^2}\right]$	lb.
γ is the adjusted ratio of specific heats (taken as 1.3)		
U is the total volume behind the seated projectile		in.^{3}
V is the muzzle velocity of the projectile		in./sec.
A is the cross sectional area of the bore		in.^{2}
L is the projectile travel to muzzle		in.
ρ is the solid propellant density		lb./in.^{3}
D is the bore diameter		in.
386 is a mass conversion factor (dimensionless)		
P_m is the space mean pressure at muzzle time		lb. wt./in.^{2}
P_{max} is the space mean pressure at the time of maximum pressure		lb. wt./in.^{2}

The Lagrange correction is used in the examples to convert space mean pressure to breech pressure as follows:

$$\text{Space mean pressure} = \frac{1+C/3m}{1+C/2m}\ (\text{Breech pressure})$$

When the given information in a problem determines any two of the reduced variables the other three can be obtained from the chart. When the charge mass (C) is to be determined, an iteration process is necessary. To avoid this, a collinear diagram has been developed which gives the quantity 1/r directly. The charge mass can then be computed from equation 4. The diagram and the procedure for its use can be found in BRL Memo Report No. 1299.

The reduced variable, W, is plotted along the upper edge of the chart. This variable has limited usefulness since it is necessary to know the propellant burning constant under firing conditions in order to calculate W. Usually this is not known and because of the squared dependence large errors in W will result if closed bomb burning constants are used.

$$W = \frac{CA^2}{\rho^2 S^2 B^2 FM}$$

where

S is the total surface area of propellant

B is the burning constant of the propellant under firing conditions and the other parameters have been defined earlier.

EXAMPLE NO. 1

No. 1 (Data taken from a .30 Cal firing record)

Given:

m = 150.5 grains = .0215 lb.

C = 50 grains = .00714 lb.

$F = 4.023 \times 10^6$ in. lb./lb.

ρ = .05708 lb./in.^{3}

U = .258 in.^{3}

A = .0735 in.^{2}

L = 21.79 in.

Peak Breech pressure = 35,890 lb./in.^{2}

Determine the muzzle velocity and pressure.

The Lagrange correction gives

$$P_{max} = \frac{1+C/3m}{1+C/2m}\ 35{,}890 \text{ lbs./in.}^2 = 34{,}200 \text{ lbs./in.}^2$$

Equation 3 gives $x = 13.05$

Equation 4 gives $r = 6.31$

From the chart (Figure 1)

e = .352

z is estimated to be .566

y is estimated to be .316

from which the muzzle velocity calculated from equation (1) is given by

$$\frac{\dfrac{386eFC}{.15} - \dfrac{DL\ 10^6}{2}}{(m+C/3)} = 31{,}000 \text{ in./sec.} = 2582 \text{ ft./sec.}$$

The observed muzzle velocity at this firing was 2565 ft./sec.
The space mean pressure at muzzle time is estimated to be $.316\ P_{max}$ =
10,800 lbs./in.^{2}

When experimental results of a firing are used to compute r, x, and e, and the level curves having these values are plotted on the chart, a triangle is obtained. Complete accuracy is obtained by the three lines intersecting at a point, otherwise increasing accuracy is indicated by the smallness of the triangle. The values of r, x, and e have been calculated and plotted in Figure 2 for the example given here and nine other firings.

Richard C. Strittmater

RICHARD C. STRITTMATER

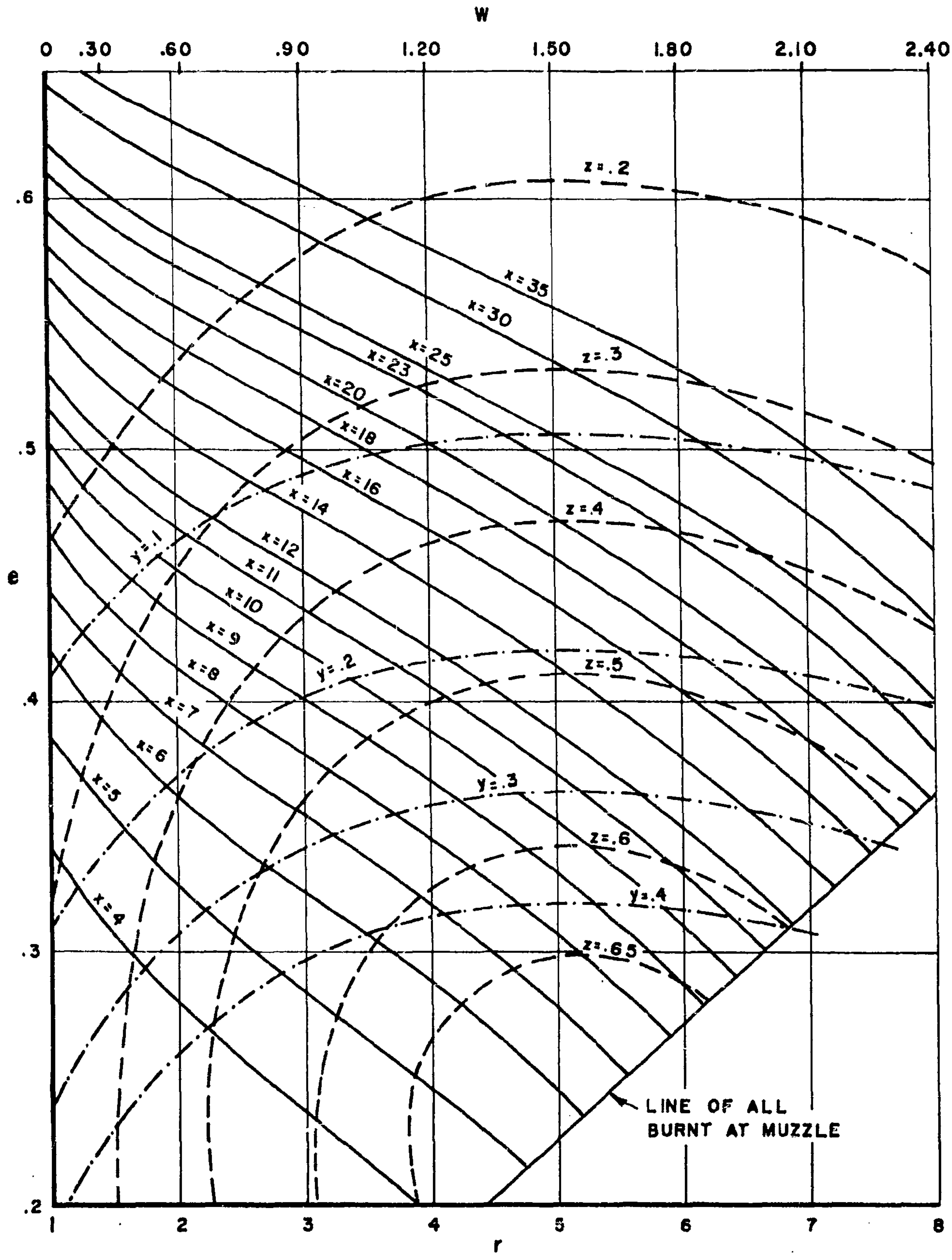
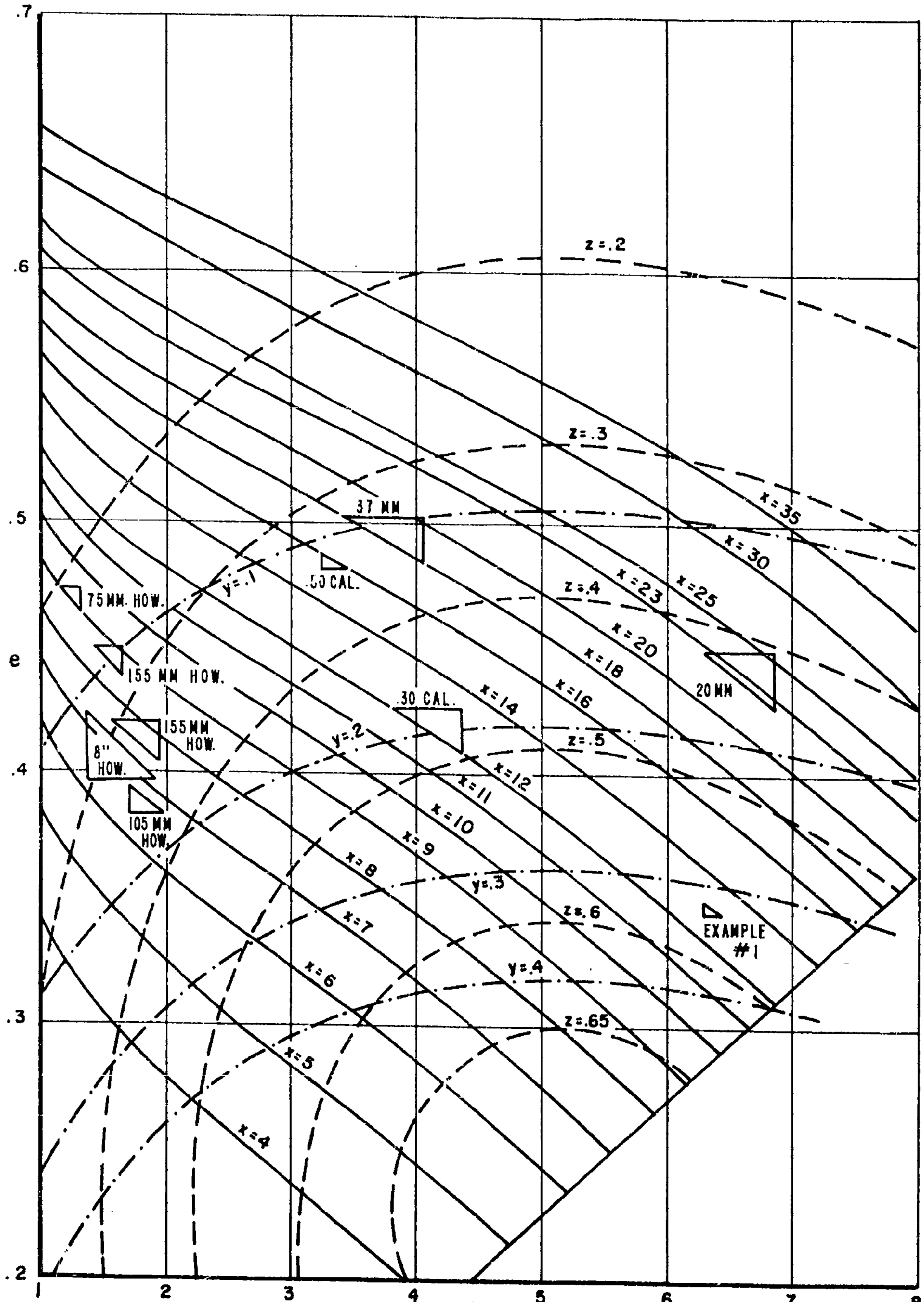

W
0
.30
.60
.90
1.20
1.50
1.80
2.10
2.40
e
.6
.5
.4
.3
.2
r
1
2
3
4
5
6
7
8
z=.2
z=.3
z=.4
z=.5
z=.6
z=.65
x=35
x=30
x=25
x=23
x=20
x=18
x=16
x=14
x=12
x=11
x=10
x=9
x=8
x=7
x=6
x=5
x=4
y=.1
y=.2
y=.3
y=.4
LINE OF ALL
BURNT AT MUZZLE

FIGURE I



.7
.6
.5
.4
.3
.2
e
1
2
3
4
5
6
7
8
r
z=.2
z=.3
z=.4
z=.5
z=.6
z=.65
y=.1
y=.2
y=.3
y=.4
x=35
x=30
x=25
x=23
x=20
x=18
x=16
x=14
x=12
x=11
x=10
x=9
x=8
x=7
x=6
x=5
x=4
37 MM
.50 CAL.
.30 CAL.
20 MM
75 MM. HOW.
155 MM HOW.
155 MM HOW.
8" HOW.
105 MM HOW.
EXAMPLE #1

FIGURE 2

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